Delta Modulation Using Python

(Digital Communication)

School: School of Engineering
University: Jawaharlal Nehru University
Year: 3rd Year (5th Semester)
Choudhary Sumit Jaswant (22/11/EE/010)
Vaibhav Mishra (22/11/EE/027)
Siddharth Kumar (22/11/EE/028)

Introduction

Definition: Delta Modulation (DM) is a technique used to convert an analog signal into a digital signal. It encodes the difference between successive samples of the signal into a binary bit stream.

DM is one of the simplest forms of modulation. By transmitting only the change in information (increase or decrease in signal amplitude), DM reduces the amount of data that needs to be sent hence reducing bandwidth requirement. The hardware required for DM is less complex compared to other modulation techniques.

Therefore, used in digital communication systems to reduce the bandwidth required for transmission.

Working Principle of Delta Modulation/Demodulation

Sampling: The analog signal is sampled at a rate much higher than the Nyquist rate to ensure accurate representation.

Quantization: Instead of quantizing the absolute value of the input signal, delta modulation quantized the difference between the current and the previous sample. This difference is called the delta (Δ).

Encoding: The quantized difference is encoded into a 1-bit data stream. If the current sample is higher than the previous one, a ‘1’ is transmitted; if it is lower, a ‘0’ is transmitted.

Transmission: The 1-bit data stream is transmitted to the receiver.

Demodulation: At the receiver end, the signal is reconstructed by integrating the received 1-bit data stream. A ‘1’ increases the signal by a fixed step size, while a ‘0’ decreases it by the same step size.

Filtering: A low-pass filter is used to smooth out the reconstructed signal, reducing noise and approximating the original analog signal.

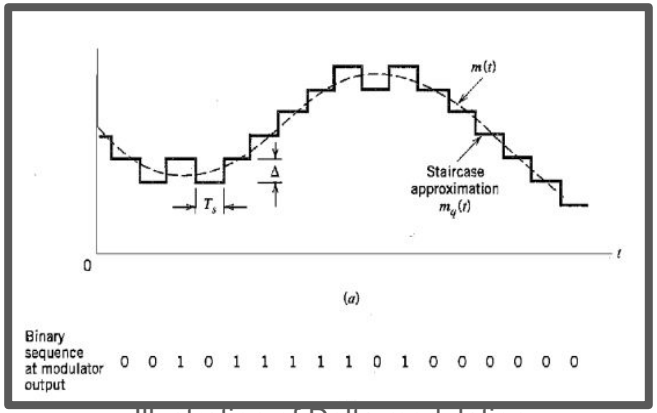


Illustration of Delta modulation

Basic Overview of the Python Code

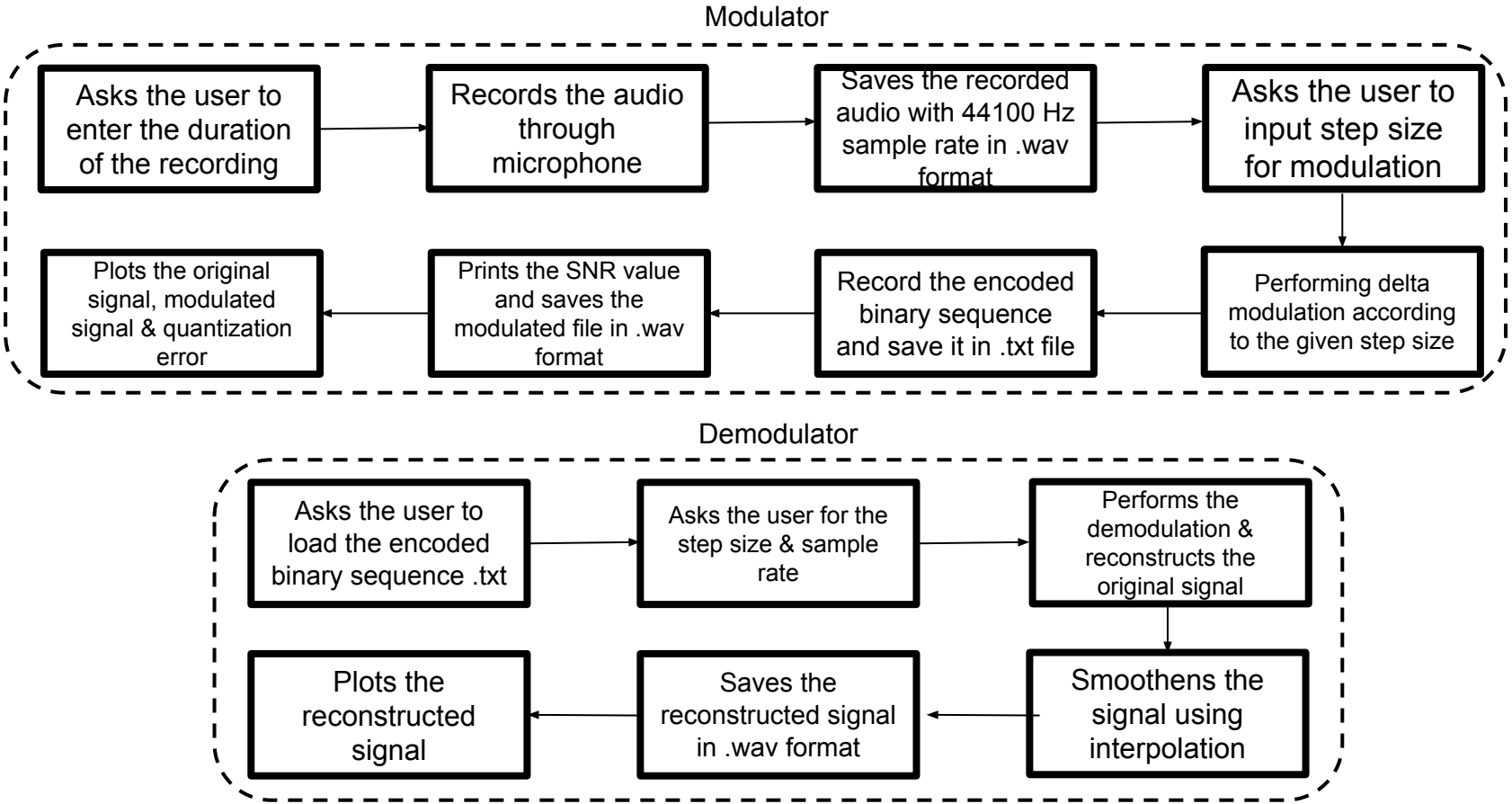
This python code captures real-time audio using a microphone, performs delta modulation on the recorded signal, and allows the user to save both the original and delta-modulated audio. The encoded binary sequence is saved in a text file. It also calculates the Signal-to-Noise Ratio (SNR), and visualizes the results through plots.

These are the Python libraries that are used in these code:

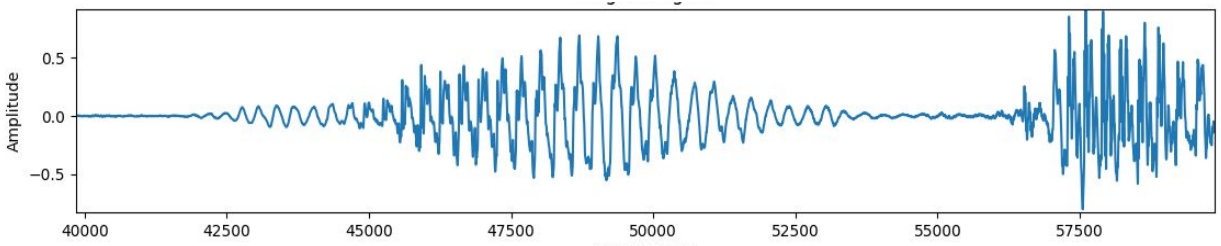
- **numpy:** Used for numerical operations on arrays.
- **matplotlib:** Used for plotting graphs to visualize the audio signals.
- **tkinter:** Provides graphical user interface (GUI) features for opening file dialogs.
- **sounddevice:** Used to record real-time audio from the microphone.
- **scipy.io.wavfile.write:** For writing audio data into a WAV file.

Furthermore, the binary sequence can be used to reconstruct the original audio back using the demodulator python code if the step size & sample rate is known.

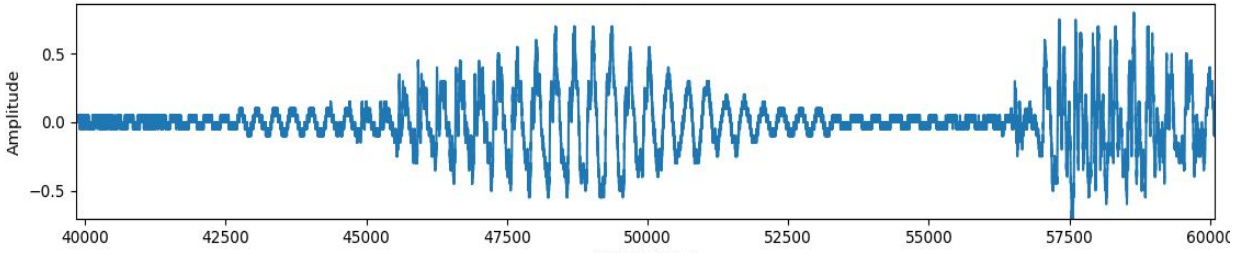
Process of Modulation/Demodulation



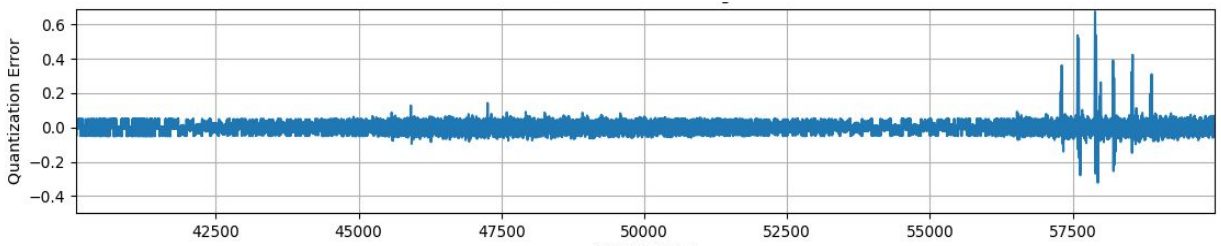
Result (Example)



A segment of the recorded voice input



A segment of Delta Modulated Output



A segment of the Quantization Error

For this case, the step size input was 0.05 and SNR value produced was 9.27 dB (and encoded binary output is saved in .txt file)

Advantages & Disadvantages

Advantages:

- Its design and implementation is simple, required less complex hardware & fewer components compared to other techniques.
- Lower bit rate so lower bandwidth used in this so efficient transmission over channels.
- With limited bandwidth, error calculation is easy and quality of output signal can be improved with minimal changes in step size.

Disadvantages:

- Slope overload distortion → it occurs when input signal changes very rapidly.
- Granular noise → if the step size is too large it may introduce granular noise during small signal changes.
- Upper both issues arises due to its fixed step size regardless of signal variations.
- Limited dynamic range due to fixed step size this can lead to poor performance and increase noise in modulating signal.
- Bit rate is still higher than adaptive techniques.

Advancements

Several advancements can be achieved to improve DM and resolve its issues as in Slope overload distortion and Granular noise ,fixed step size. These advance techniques enhance signal quality, increases efficiency and error can be reduced.

Adaptive delta modulation -> ADM dynamically adjust the step size of the modulator based on input signal rate of change when input signal changes slowly small step size is taken ,and for rapidly changing signals a larger step size is used.

Few others techniques are – Sigma delta modulation used in audio and DACs. This method reduce quantization noise with efficiency.

DPCM, Linear Delta modulation, Delta sigma modulation, Predictive delta modulation are other examples.

Conclusion

In conclusion, Delta Modulation is a simplified and efficient technique for converting analog signals into digital form by encoding the difference between successive samples. Its simplicity reduces both the complexity and bandwidth required for signal transmission, making it ideal for low-bitrate applications such as telephony. While Delta Modulation can suffer from issues like slope overload and granular noise, its basic principles form the foundation for more advanced techniques like Adaptive Delta Modulation. Overall, it remains a relevant and valuable tool in digital signal processing, offering a balance between simplicity and functionality.

Repository

https://github.com/siddharthk7704/delta-modulation/tree/main